

Search for First Generation Leptoquarks at DØ in Run2

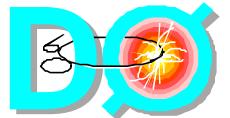
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DPF Meeting, May 2002
Williamsburg, Virginia



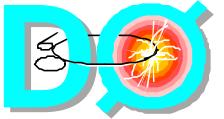


Outline



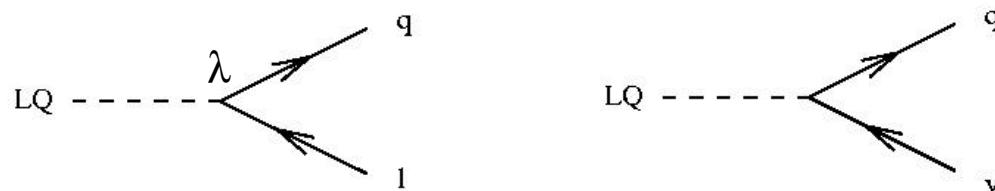
- Leptoquark Phenomenology
- Run2 Upgrade and DØ Detector
- Data Selection
- Background
 - QCD
 - Drell-Yan
 - Top
- Signal
- Error Estimation
- Results





Leptoquark Phenomenology

- Leptoquarks are predicted in many SM extensions
 - Grand Unified Theories
 - Technicolor, etc.
- Couple to both leptons and quarks

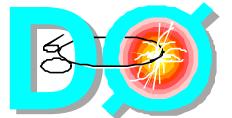


- Carry color, fractional electric charge, lepton number, baryon number
- Scalar (spin 0) or Vector (spin 1)
 - Vector coupling is model dependent
 - Yang-Mills coupling, Minimal coupling
- Three generations
 - Intergenerational mixing constrained by FCNC

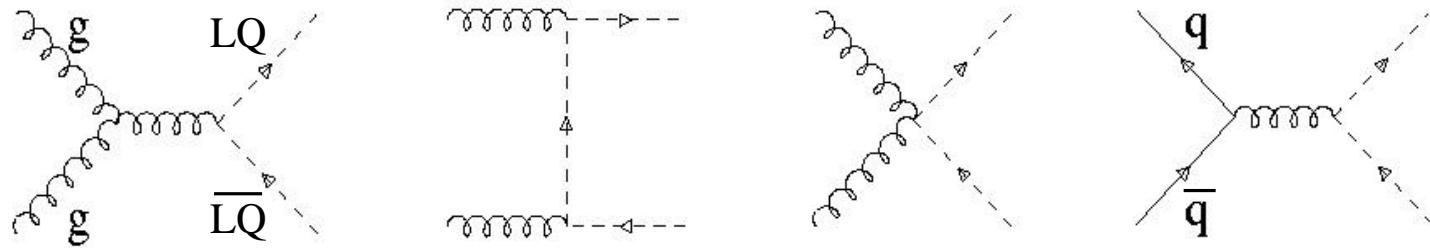




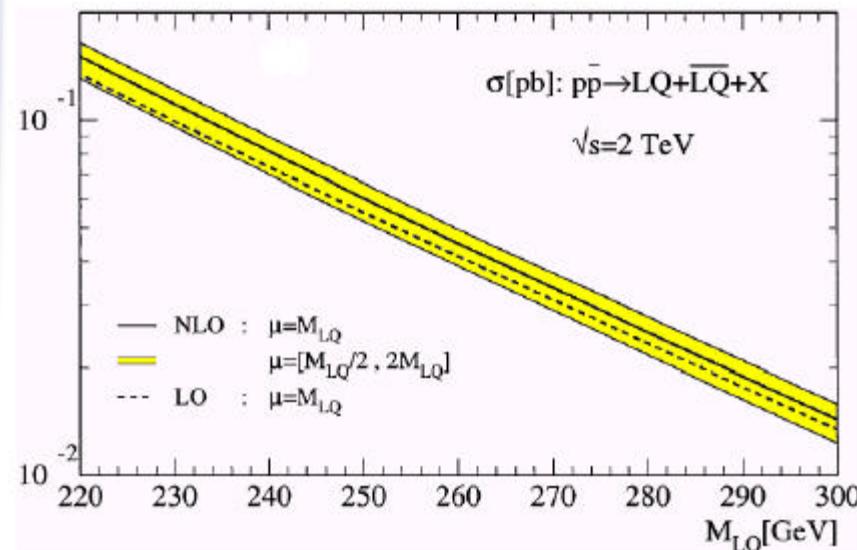
Leptoquark Production



- Leptoquark pair production at the Tevatron
 - gluon fusion (dominant), quark anti-quark annihilation
 - Insensitive to coupling constant λ



- NLO Cross Sections



NLO Scalar xsection calculated by:
M. Krämer, et. al., PRL **79**, 341 (1997)

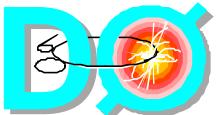
Only LO calculation for vector LQs:
J. Blümlein, hep-ph/9811271 (1998)

Cross section for vector LQs generally
larger than that for scalar LQs





Looking for Leptoquarks



- Leptoquark Decay
 - $LQ \rightarrow l^\pm q$ or $n q$ $\beta \equiv$ Branching Ratio ($LQ \rightarrow l^\pm q$)
 - Signature: 2 Leptons + 2 Jets, Lepton + Jet + E_T , 2Jets + E_T
- \triangleright 1st gen. LQ search in 2e2j channel with Run2 data
- Previous mass limits of first generation LQ

DØ Run1 (Lum = 115 pb⁻¹)

$\beta =$ $BR(LQ \rightarrow eq)$		Scalar Mass Limit GeV/c ²	Vector Minimal Coupling GeV/c ²	Vector Yang-Mills Coupling GeV/c ²
DÆ	1	225	292	345
	0.5	204	282	337
	0	98	238	298

Phys. Rev., D64, 092004 (2001)

Run1 DØ / CDF combined

$\beta = 1$, scalar LQ : 242 GeV

hep-ex/9810015 (1998)

LEP2 latest results

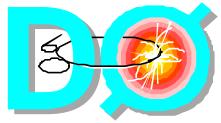
$\beta = 1$, scalar LQ : ~ 85 GeV

$\beta = 1$, vector LQ : ~ 90 GeV

(coupling dependent)

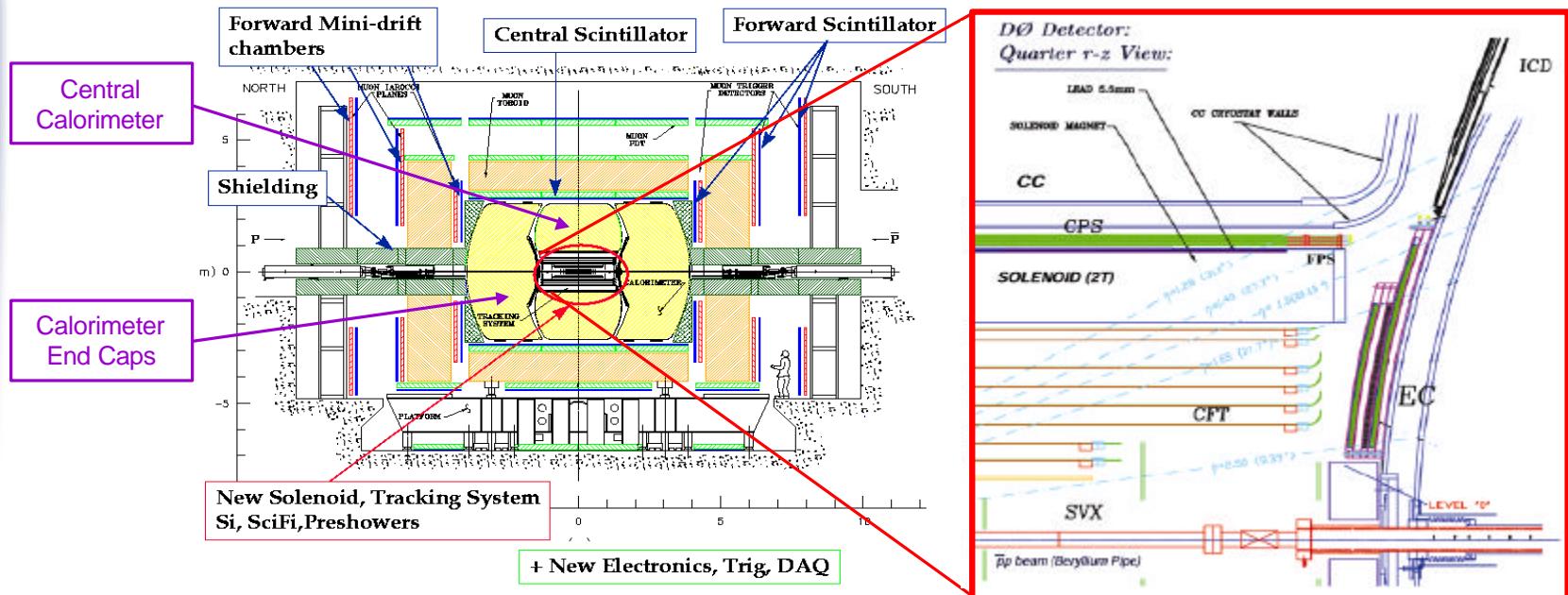
Eur. Phys. J., C13, 15-27 (2000)

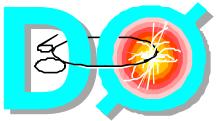




Run2 Upgrade

- Tevatron Upgrade
 - Higher energy: (larger production cross sections)
 \sqrt{s} : 1.8 TeV (Run 1) \rightarrow 1.96 TeV (Run 2)
 - Increased luminosity:
0.1 fb^{-1} (Run 1) \rightarrow 2 fb^{-1} (Run 2a) \rightarrow 15 fb^{-1} (Run 2b)
- D \emptyset Experiment Upgrade
 - Tracking, Calorimeter electronics, Muon, etc.





Data Selection

- Select from $\ell^+ \ell^-$ trigger (Nov 2001 – April 2, 2002)
 - Integrated luminosity $4.0 \pm 0.4 \text{ pb}^{-1}$
- Event selection

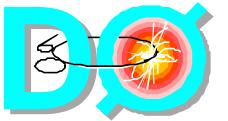
<i>Selection Criteria</i>	<i>Events</i>
Pre-selection & Trigger selection	1649
2 EM object ($E_T > 25 \text{ GeV}$, in CC/EC)	435
2 or more jets ($E_T > 20 \text{ GeV}$, $ \eta < 2.5$, $\Delta R_{ej} > 0.7$)	10
Z veto ($M_{ee} < 82 \text{ GeV}$ or $M_{ee} > 100 \text{ GeV}$)	5

$\ell^+ \ell^-$ – Electro-Magnetic

$\ell^+ \ell^-$ – 2 Electro-Magnetic objects

$$\Delta R_{ej} = \sqrt{\Delta\eta_{ej}^2 + \Delta\phi_{ej}^2}$$

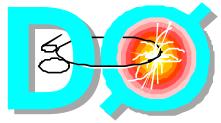




Background

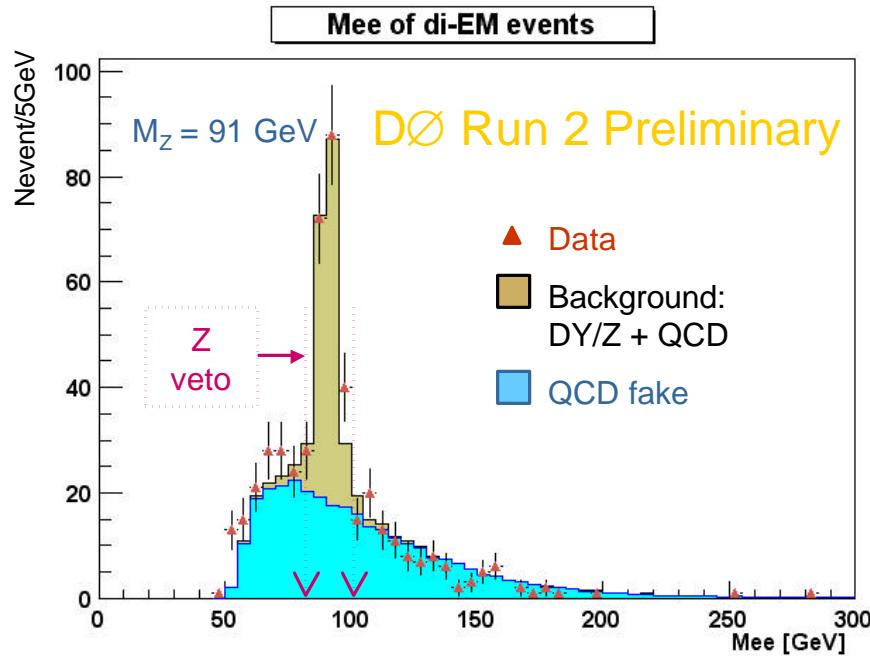
- QCD background (dominant)
 - multi-jet data
 - 2 jets fake EM objects
- Drell-Yan/Z background
 - $Z/g^* + jets \rightarrow e^+e^- + jets$
- Top background
 - $t\bar{t} \rightarrow l\bar{l} + jets$





Drell-Yan background

- Use Monte Carlo samples in all mass ranges
 - Compare di-EM data with (QCD fake BKG + Drell-Yan MC)



no jet requirement
no Z veto requirement

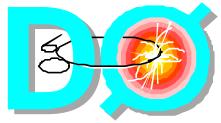
Data : 471 events
BKG : 473 ± 93 events

- DY/Z : 167 ± 17 events
(error from MC xsec)
- QCD : 306 ± 76 events
(error from fake rate)

- Drell-Yan background (of 2e2j events)
 0.3 ± 0.1 events
(Error dominated by jet energy scale)

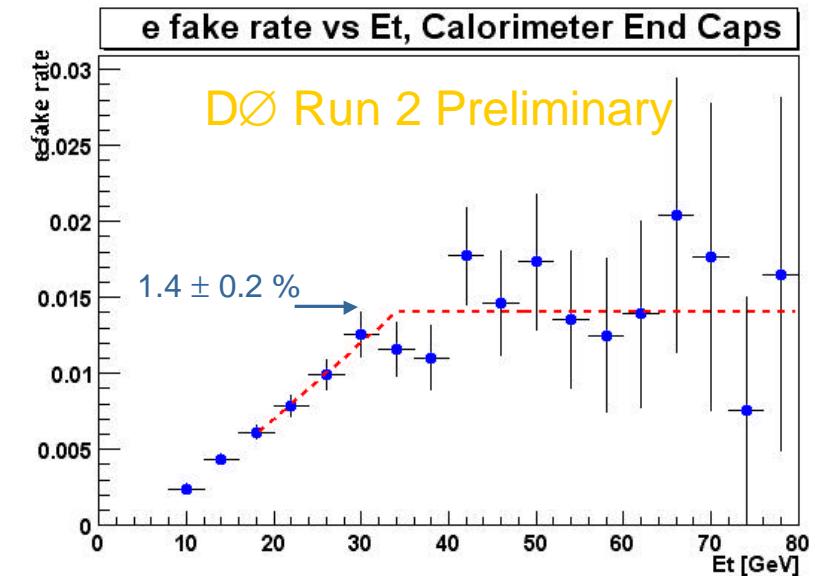
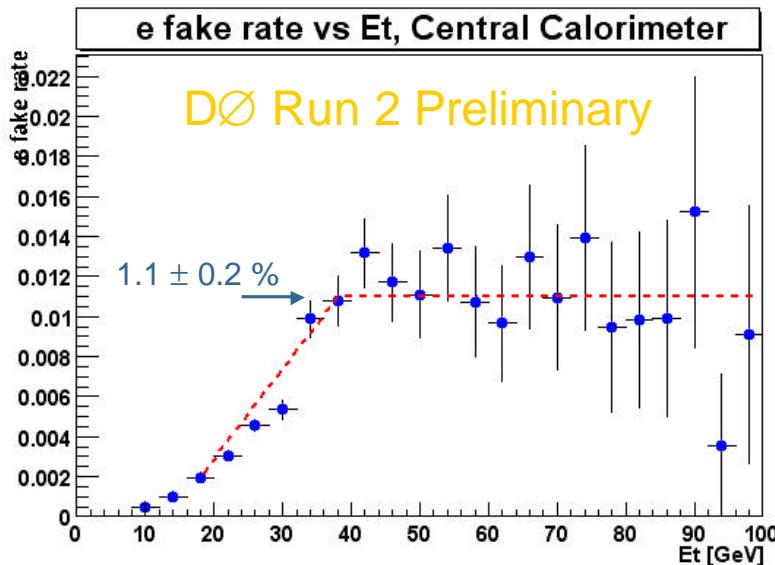
require 2 jets
require Z veto





QCD background

- The probability that a jet fakes an electron

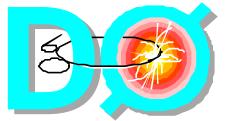


Very preliminary: loose electron identification and no track match requirement.

These fake rates will decrease with improved electron identification.

- QCD background
 7.8 ± 3.9 events
(Error dominated by jet energy scale)





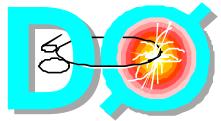
Top background

- Top Monte Carlo sample
 - Top mass = 174 GeV
 - $t\bar{t} \rightarrow W^+ W^- b\bar{b}$, $W \rightarrow l n$ (including e, m, t)
 - Cross Section \times Branching Ratio = 0.74 ± 0.21 pb
 - Apply all cuts to MC sample:
Total Acceptance = 0.010
- Very small contribution from top background
 0.03 ± 0.01 events
(error dominated by top cross section uncertainty)



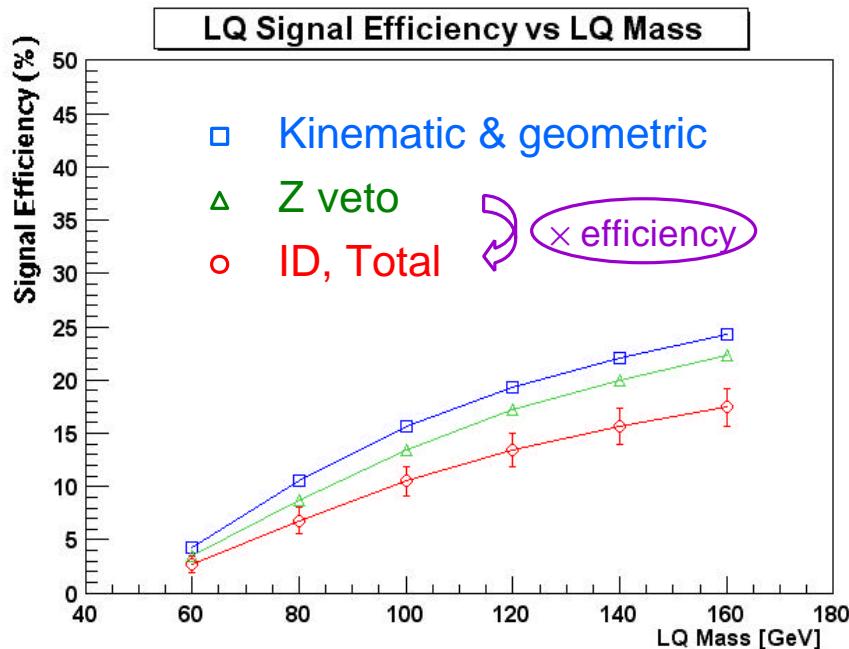


LQ Signal



- Leptoquark sample acceptance
 - Kinematic & geometric acceptance
 - EM trigger efficiency ($E_T^e > 25 \text{ GeV}$)
 - Particle identification efficiency
 - EM identification efficiency ($E_T^e > 20 \text{ GeV}$)
 - Jet reconstruction efficiency ($E_T^j > 20 \text{ GeV}$)
 - Jet quality cut efficiency ($E_T^j > 20 \text{ GeV}$)

varies with LQ mass
100 %
78 %
 $94 \pm 6 \pm 5 \%$
95 %
99 %



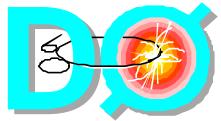
For example:

LQ mass = $100 \text{ GeV}/c^2$

4.7 ± 0.6 events @ 4.0 pb^{-1}

Note: The LQ mass of $100 \text{ GeV}/c^2$ corresponds to the expected sensitivity for the luminosity of 4 pb^{-1} luminosity.





Error Estimation

- Signal errors

<i>Source of error</i>	<i>error</i>
Particle ID	8 %
Jet Energy Scale	25 % (60 GeV) 9 % (100 GeV) 4 % (160 GeV)
PDF and Q^2	5 %
MC Statistics	2 %
Total	27 % (60 GeV) 13 % (100 GeV) 10 % (160 GeV)

- Background errors

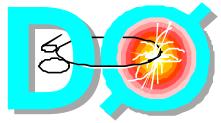
<i>Background</i>	<i>error</i>
QCD	50 % (jet energy scale)
Drell-Yan	50 % (jet energy scale)
Top	40 % (top cross section)

- Luminosity error: **10 %**

Error values are very preliminary.

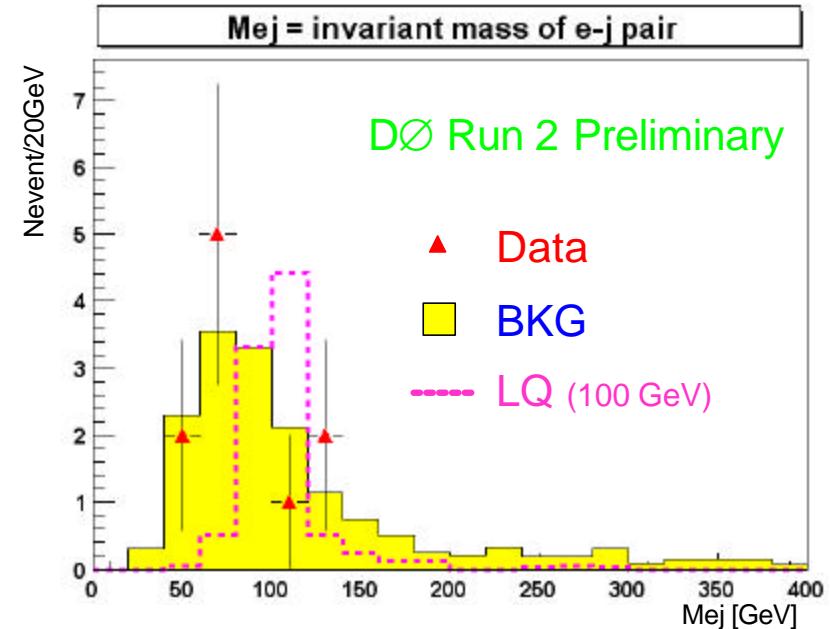
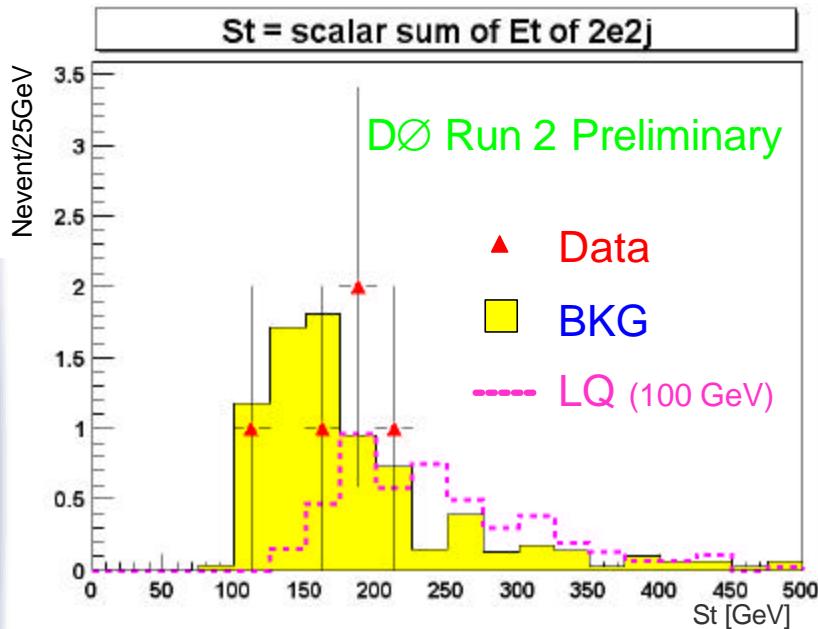
Improvements to come on Particle ID and Jet Energy Scale.





Results

- Compare data and background distributions



Data :

5 events

Total Background :

8.1 ± 4.0 events

• QCD :

7.8 ± 3.9 events

• Drell-Yan :

0.3 ± 0.1 events

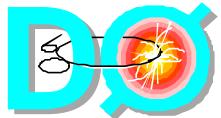
LQ ($m = 100$ GeV) :

4.7 ± 0.6 events





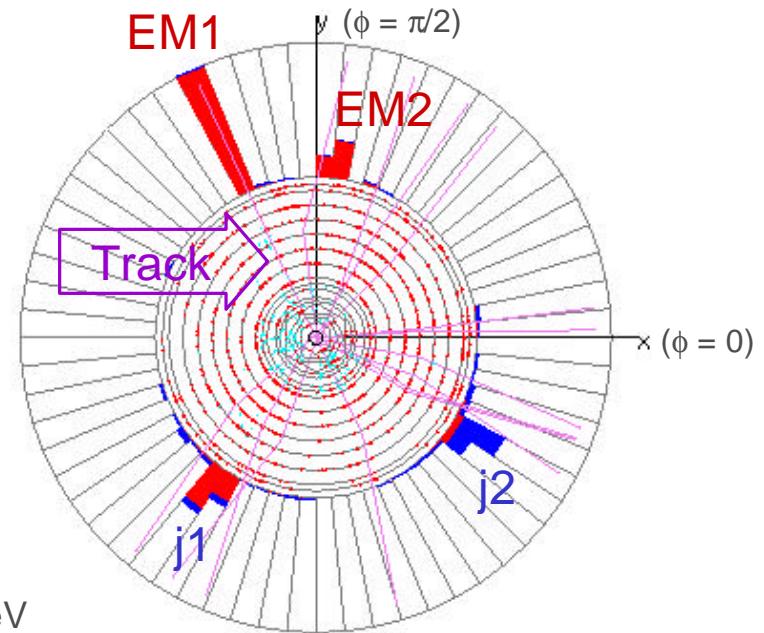
Event Display



- The most energetic event
 - $S_T = 224 \text{ GeV}$
 - 1 EM has track match

X:Y view

E_T scale: 56 GeV

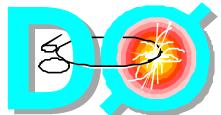


EM1	EM2	j1	j2
$E_T(\text{cal}) = 65.1 \text{ GeV}$ $\eta = 0.71, \phi = 2.00$ Track match	$E_T(\text{cal}) = 30.5 \text{ GeV}$ $\eta = 1.72, \phi = 1.47$	$E_T(\text{cal}) = 70.9 \text{ GeV}$ $\eta = 1.54, \phi = 4.07$	$E_T(\text{cal}) = 57.7 \text{ GeV}$ $\eta = 2.21, \phi = 5.73$
$S_T = 224 \text{ GeV}$ $M_{\text{ee}} = 52 \text{ GeV}$ $M_{\text{ej}} = 132 \text{ GeV}, 75 \text{ GeV}$ $\cancel{E}_T = 5.0 \text{ GeV}$			





Summary



- DÆ detector operation and data processing are in good shape.
- Current data agrees well with the Standard Model.
- With increased energy and luminosity, first generation Leptoquark search can reach ~300 GeV in Run 2a, and ~400 GeV in Run 2b.
- Improved results and limit setting are expected on ICHEP (July 2002).

